Speed Control of DC Motor Using PID Controller Based on Artificial Intelligence Techniques

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Abstract— the aim of this paper is to design a speed controller of a DC motor by selection of a PID parameters using genetic algorithm (GA) and Adaptive Neuro-Fuzzy Inference System (ANFIS). DC motor could be represented by a nonlinear model when nonlinearities such as magnetic saturation are considered. To provide effective control, nonlinearities and uncertainties in the model must be taken into account in the control design.The model of a DC motor is considered as a third order system. And this paper compares three kinds of tuning methods of parameter for PID controller. One is the controller design by the Ziegler and Nichols, second is the controller design by the Genetic Algorithm method and third is the controller design by Adaptive Neuro-Fuzzy Inference System (ANFIS). The proposed methods could be applied to the higher order systems.

Keywords— *DC Motor, Genetic Algorithm, PID Controller, Ziegler Nichols Method, ANFIS.*

I. Introduction

DC motors have been widely used in industry even though its maintenance costs are higher than the induction motor. Proportional-Integral Derivative (PID) controllers have been widely used for speed and position control of DC motor. The paper achievement is to design a control system using Genetic Algorithm with considering of non linearity effective of the system. Genetic Algorithm or in short GA is a stochastic algorithm based on principles of natural selection and genetics. Genetic Algorithms (GAs) are a stochastic global search method that mimics the process of natural evolution. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time. Furthermore, the effective of applying Adaptive Neuro -Fuzzy Inference SYSTEM (ANFIS) based on genetic algorithms will be studied. The objective of this paper is to show that by employing the GA method with and without ANFIS of tuning a system, an optimization can be achieved. This can be seen by comparing the results of the GA optimized system against the Ziegler-Nichols tuned system.

II. The DC Motor Model

An electric motor converts electric energy to mechanical energy by using interacting magnetic fields. Electric motors are used for a wide variety of residential, commercial, and industrial operations.

As reference the connection for a shunt-type DC motor is illustrated in Figure (1) a shunt-wound DC motor consists of a shunt field connected in parallel with the armature. The shunt field winding is made up of many turns of small-gauge wire and has a much higher resistance and lower current flow compared to a series field winding. As a result, these motors have excellent speed and position control. Hence DC shunt motors are typically used applications that require five or more horse power. The equations describing the dynamic behaviour of the DC motor based on the schematic diagram on Figure (2) are given by the following equations;.

$$V_a = R_a \cdot i_a(t) + L_a \cdot \frac{di_a(t)}{dt} + e_b(t) \qquad (1)$$

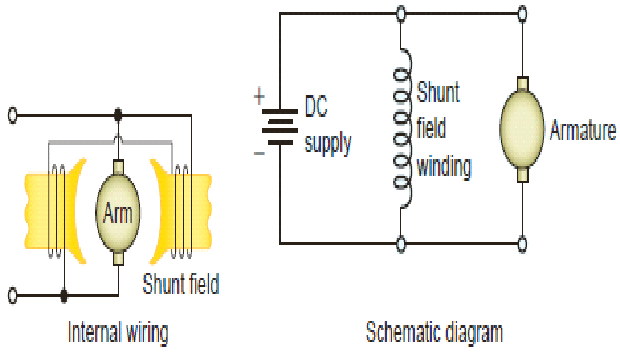

Fig. 1: Diagram of DC Shunt Motor

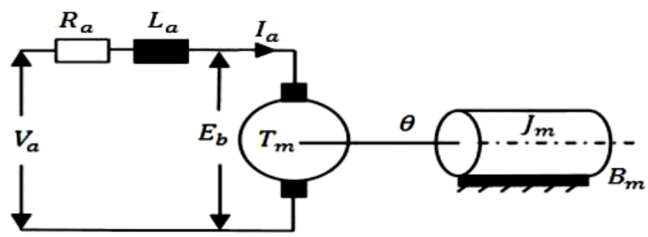

Fig. 2: the schematic diagram OF DC motor

$$e_b(t) = K_b \cdot w(t) \quad (2)$$

$$T_m(t) = K_T \cdot i_a(t) \quad (3)$$

$$T_m = J_m \cdot \frac{dw(t)}{dt} + B_m \cdot w(t) \quad (4)$$

Then,

$$T_m = J_m \cdot \frac{d\theta^2(t)}{dt} + B_m \cdot \frac{d\theta(t)}{dt} \quad (5)$$

After simplification and taking the ratio of θ(s)/ v(s).

The transfer function will be given blew,

Θ(s) / v(s)=Kb / [J La S3 + (Ra J+B La)S2 +(Kb2+Ra B)S]

(6)

Where;

V_a = armature voltage (V), R_a= armature resistance (Ω), L_a= armature inductance (H), I_a = armature current (A), E_b= back emf (V) w = angular speed (rad/s), T_m = motor torque (Nm) θ = angular position of rotor shaft (rad), Jm J_m = rotor inertia (kg m^2 m^2) B_m = viscous friction coefficient (Nms/rad), K_T = torque constant (Nm/A) K_b = back emf constant (Vs/rad). The DC motor under study has the following specifications and parameters are given in Table (1):

Table: (1) the Specification and Parameters of DC Motor

Specification	2 hp, 230 V, 8.5 Amperes, 1500 rpm
Parameters	
2.45Ω	R_a (Armature resistance)
0.035H	L_a (Armature inductance)
1.2Vs/rad	K_b (Back emf)
0.022 kgm^2	J_m (Moment of inertia)
0.5*10^{-3} (Nms/rad)	B_m (Frictional constant)

The transfer function of the used DC Motor is:

$$\frac{\theta(s)}{V_a(s)} = \frac{1.2}{0.00077s^3 + 0.0539s^2 + 1.441s} \quad (7)$$

III. TUNING OF PID CONTROLLER USING SEVERAL METHODS

A. *Ziegler-Nichols Tuning Method*:

There are two methods for determination of the parameters of PID controllers called Ziegler-Nichols tuning rules. But the widely accepted method for tuning the PID controller is straightforward method. First, set the controller to P mode only. Next, set the gain of the controller (K_p) to a small value. If K_p is low the response should be Sluggish. Increase K_p by a factor of two and Keep increasing K_p (by a factor of two) until the response becomes oscillatory. Finally, adjust K_p until a response is obtained that produces continuous oscillations. This is known as the ultimate gain (K_u) or . Note that the period of the oscillations is known as ultimate period (T_u).

The steps required for the method are given below:-

- The integral and derivative coefficients have to set (gains) to zero.
- Gradually increase the proportional coefficient from zero to until the system just begins to oscillate continuously (sustained oscillation). The proportional coefficient at this point is called the ultimate gain (K_u).

▪ And the period of oscillation at this point is called ultimate period (T_u).

The Ziegler-Nichols Tuning Rule are then obtained from the following Table (2),

Table: (2) Ziegler-Nichols Tuning Rule Based

Controller Type	Kp	Ki	Kd
PID	Ku /1.7	Tu/2	Tu/8

It was found that, the critical gain Ku = 84and the critical period Tu = 0.15 sec and PID controller is shown in Figure (3), where K_p=49.41, K_i=0.075 and K_d=0.01875 and also the out put response of the system is shown in Figure (4).

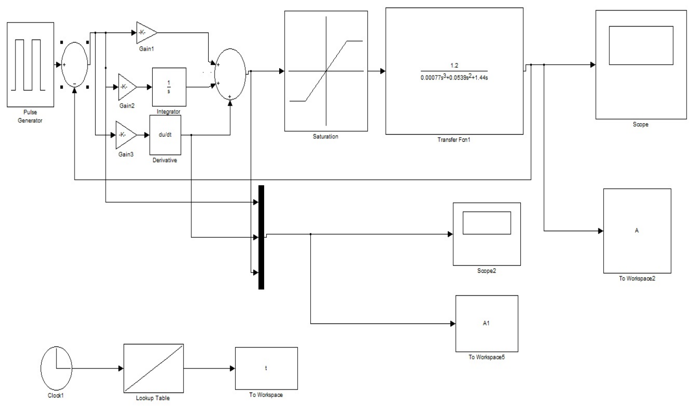

Fig. 3: Block Diagram For The Complete System Using PID Controller Tuning With Ziegler-Nichols

From the above response, we can analyze the system. We can analyze the following parameters:

- Maximum Overshoot, Mp
- Settling time, ts

The Maximum Overshoot, Mp of the system is approximately 0.02. The Settling time, ts is about 0.8 sec. From the analysis above, the system has not been tuned to its optimum. So we have to go for genetic algorithm approach.

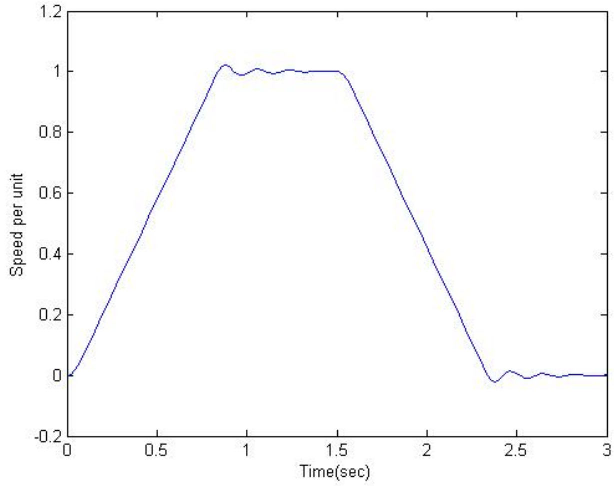

Fig. 4: Response of the system Using PID Controller Tuning With Ziegler-Nichols

B. *Genetic Algorithm Method:*

GA has been recognized as an effective and efficient technique to solve optimization problems. GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem which performance is evaluated by a fitness function. Basically, GA consists of three main stages: Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops when reaching individuals that represent the optimum solution to the problem. The Genetic Algorithm Process Architecture is shown in Figure(5).

The proposed PID controller with applying Genetic Algorithm Method is given in Figure (6), and also The genetic algorithm gain values for the tuning is given below in Table(3). The out put response of the system is showen in Figure (7), and we can analyze the system for the previous parameters

o Maximum Overshoot, Mp
o Settling time, ts

The Maximum Overshoot, Mp of the system is approximately zero. The Settling time, ts is about 0.45 sec. we will go for studying the effect of ANFIS for PID controller based on Genetic Algorithm.

C. *Adaptive Neuro-Fuzzy Inference System (ANFIS) method:*

IS A model that maps input characteristics to input membership functions, input membership function to rules, rules to a set of output characteristics, output characteristics to output membership functions, and the output membership function to a single-valued output or a decision associated with the output.

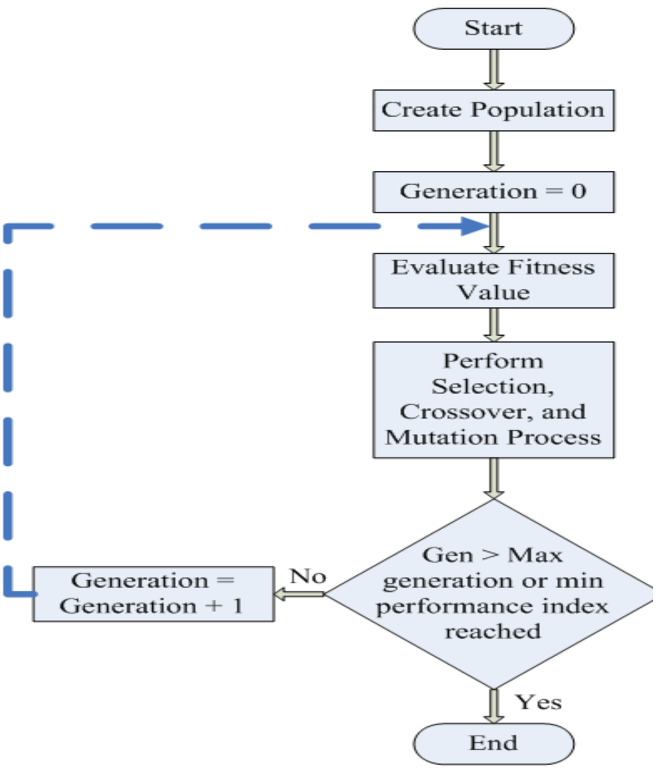

Fig. 5: Genetic Algorithm Process Architecture

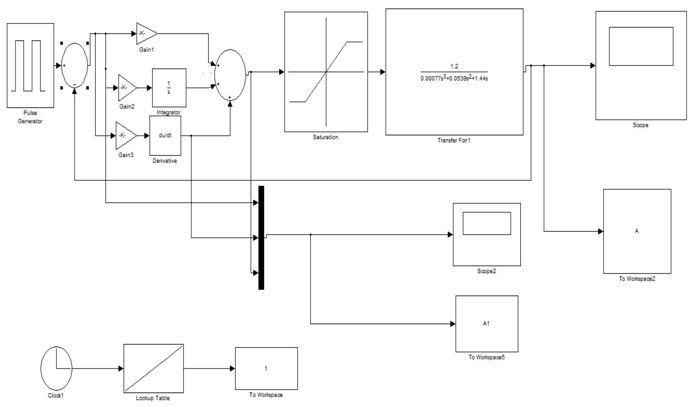

Fig. 6: Block Diagram For The Complete System Of Genetic Algorithm based PID

Table: (3) The GA based PID controller gain values

Gain Parameters	Gain Values
Kp	19.88
Ki	0.1376
Kd	0.5578

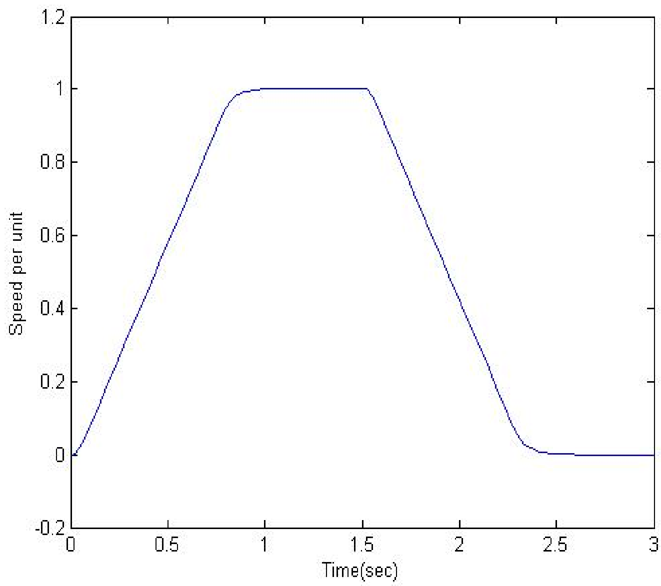

Fig. 7: Response Of Genetic Algorithm Based PID controller

ANFIS TOOL BOX:

These tools apply fuzzy inference techniques to data modeling

- The shape of the membership functions depends on parameters
- Membership function parameters were chosen automatically using these Fuzzy Logic Toolbox applications

Fuzzy Logic Toolbox software computes the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. The ANFIS tool box after training data is shown in Figure (8).

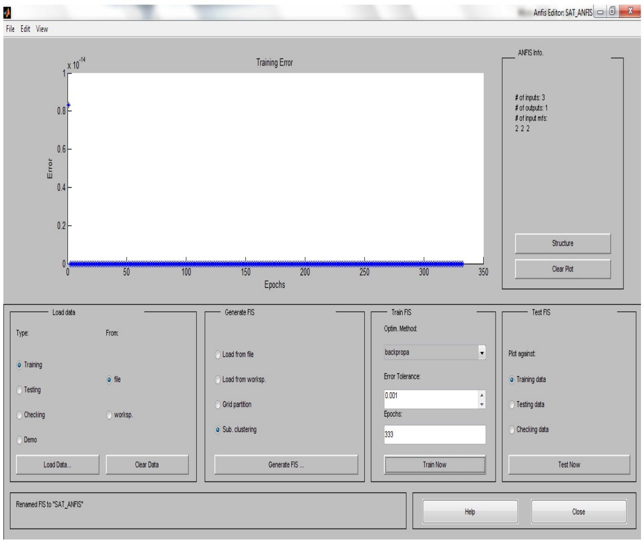

Fig 8: ANFIS Tool Box After Training Data

Then, fuzzy logic controller based on ANFIS tool box became apart of complete PID controller. The block diagram for the complete system is given below in Figure (9) and response of Adaptive Neuro-Fuzzy Inference System (ANFIS) based PID controller is shown in Figure (10).

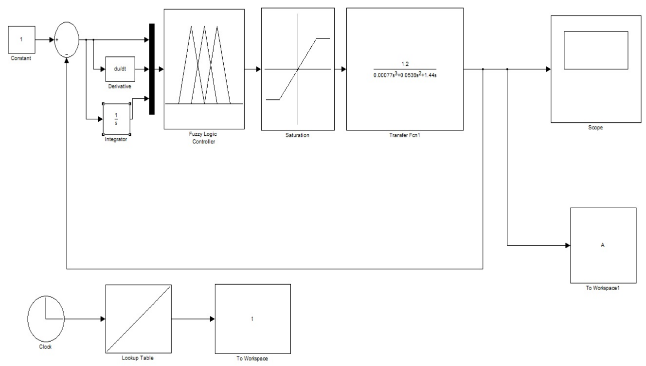

Fig. 9: block diagram for the complete system of ANFIS based PID

Also, the system for the previous parameters could be analyzed based on:

- o Maximum Overshoot, Mp
- o Settling time, ts

The Maximum Overshoot, Mp of the system is approximately zero. The Settling time, ts is about 0.5 sec.

Table (4) : Comparison between ZN, GA, and ANFIS Responses

Tuning method	Maximum overshoot	Settling time (sec)
ZN	0.02	0.8
Genetic Algorithm	—	0.45
ANFIS	—	0.5

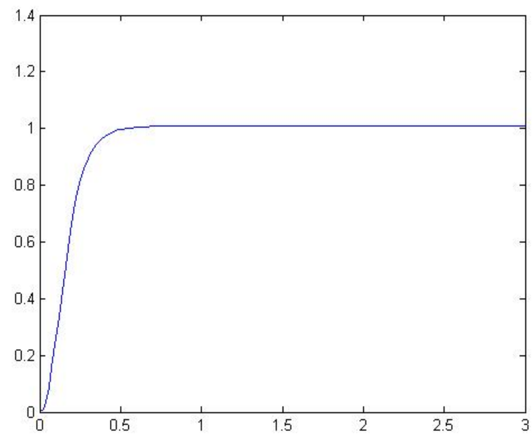

Fig.10: Response of Adaptive Neuro-Fuzzy Inference System (ANFIS) Based PID Controller

V. Conclusions

The designed PID with Adaptive Neuro-Fuzzy Inference System based GA has much faster response than response of the classical method. The classical method is good for giving us as the starting point of what are the PID values. However Adaptive Neuro-Fuzzy Inference System based GA designed PID is much better in terms of the rise time and the settling time than the conventional method. Finally the Artificial Intelligence Techniques provides much better results compared to the conventional methods. And also the error associated with the Adaptive Neuro-Fuzzy Inference System based GA is much lesser than the error calculated in the conventional scheme.

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